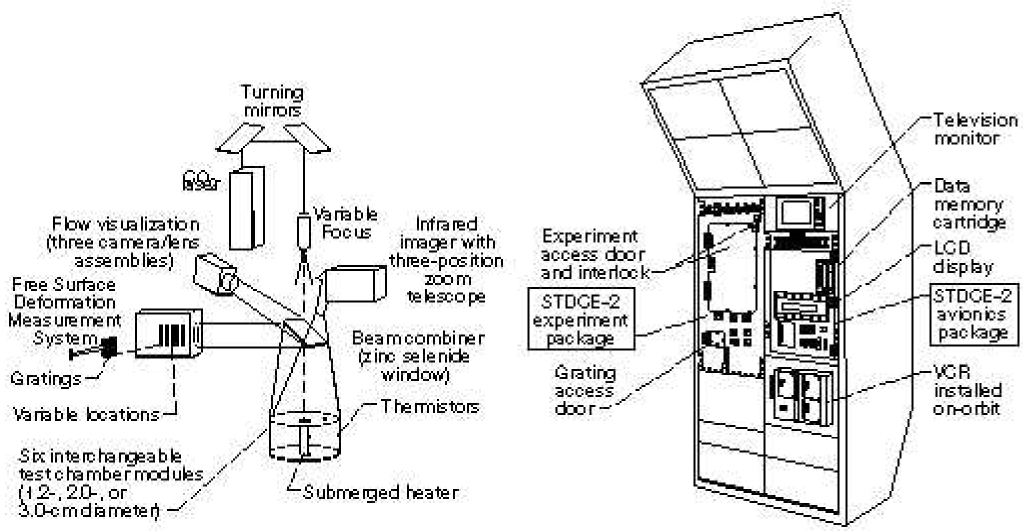
Surface Tension Driven Convection Experiment Completed

In the production of high-tech crystals, metals, alloys, and ceramics, materials are heated until they form a liquid or vaporize into a gas and then are cooled until they solidify. During this process, unwanted flows in the liquids and gases, created as the material heats and cools, often cause defects that can keep these materials from performing as predicted or designed. Advanced products, such as the crystals used to make computer chips and infrared detectors, require material that is as free from defects as possible.

In microgravity, defects due to buoyancy-driven flows are greatly reduced; however, other fluid motions that are difficult to study on Earth become more prominent in affecting crystal quality. Temperature variations along the surfaces that are not in contact with a container, called free surfaces, create fluid motions called thermocapillary flows. These flows are very difficult to measure accurately in Earthís gravity. Gravity also causes flat surfaces to form on liquids. In microgravity, investigators can study the different surface shapes that occur and how these shapes affect the thermocapillary flows.

The Surface Tension Driven Convection Experiment (STDCE) was designed to study basic fluid mechanics and heat transfer on thermocapillary flows generated by temperature variations along the free surfaces of liquids in microgravity. STDCE first flew on the USML-1 mission in July 1992 and was rebuilt for the USML-2 mission that was launched in October 1995. This was a collaborative project with principal investigators from Case Western Reserve University (CWRU), Professors Simon Ostrach and Yasuhiro Kamotani, along with a team from the NASA Lewis Research Center composed of civil servants and contractors from Aerospace Design & Fabrication, Inc. (ADF), Analex, and NYMA, Inc.

Oscillatory thermocapillary flows were studied under a variety of boundary conditions during the USML-2 mission--a total of 55 tests were conducted. STDCE-2 used 2-centistoke silicone oil and smaller test cells than were used for STDCE-1 (STDCE-2 cell diameters were 1.2, 2.0, and 3.0 cm) in six interchangeable test modules: three with laser heating (constant flux) and three with submerged heaters (constant temperature). New optics permitted laser heating of small zones (0.5 to 6 mm in diameter).



Left: Optical systems for STDCE-2. Right: STDCE-2 in Spacelab rack.

The Free Surface Deformation Measurement System, a single-channel Ronchi method that produced fringes in a video picture, was used to determine small deviations from the flat oil surface with slopes from 5 to 30 µm/ml. Other video data were produced by the three-dimensional flow-visualization system and an infrared imager with an adjustable telescope. Three video pictures (infrared imager, flow visualization, and free surface deformation) were recorded on a three-deck VCR and were downlinked, with the digital measurement data, to the Payload Operations Control Center at the Marshall Space Flight Center and to the Telescience Support Center at Lewis.

The hardware performed flawlessly, with all systems performing as designed. In addition, the ability to utilize telescience--both real-time telemetry/video and ground commanding--resulted in additional data. It was like "being there" to operate the experiment personally, allowing procedure changes to help in defining the transition point from steady flow to oscillatory flow in real time. Also, CWRU graduate students monitored the experiment at Lewis and provided additional feedback to the team at the Payload Operations Control Center.

In March 1996, results were shared with the USML-2 payload crew, whose hard, effective work made STDCE a success. The preliminary data supported the CWRU thermocapillary flow theories, which predict the importance of a second critical parameter. The transition to oscillatory flow occurred at a much lower point in low gravity and could be observed in the 3-cm test cell. As predicted by the CWRU theory, the transition point increased as the surface shape was made more concave or the aspect ratio decreased. Additional data, taken at heating levels well above the transition point, demonstrated some erratic flow and temperature patterns. Data analysis will be completed next year.

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Bibliography

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